REPORT DOCUMENTATION PAGE

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25-09-2008	Final Report	1-Oct-2001 - 31-Aug-2008

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Applications of GIS, Advanced Sensors and Habitat Modeling in Support of Desert Tortoise Line Distance Sampling and Translocation Studies related to the Proposed Expansion of the Ft. Irwin NTC	DAAD19-01-1-0793
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
	611103

6. AUTHORS	5d. PROJECT NUMBER
Jordan Henk	
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES	8. PERFORMING ORGANIZATION REPORT NUMBER
University of Redlands Grant Administration 1200 E. Colton Avenue Redlands, CA 92373 -	

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U.S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211	ARO
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12. DISTRIBUTION AVAILILITY STATEMENT

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13. SUPPLEMENTARY NOTES

The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT

This University of Redlands (University) research program (the Desert Tortoise Project; DTP), was designed to improve terrestrial science and to explore and apply a variety of information science technology, tools, and methods to equip land managers, decision-makers and policy-makers with science-based alternatives for the recovery of the desert tortoise (Gopherus agassizii, federally-listed in 1990 as a threatened species) within the West Mojave Recovery Unit (WMRU) of Southern California, and specifically, within the context of the Ft. Irwin National Training Center (NTC) expansion area. Three key DTP research objectives were identified:

15. SUBJECT TERMS

Desert Tortoise, Gopherus agassizii, Mojave Desert, GIS, Geographic Information Science, Fort Irwin, Translocation,

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Jordan Henk
U	U	U	SAR		19b. TELEPHONE NUMBER
					909-748-8376

Report Title

ABSTRACT

This University of Redlands (University) research program (the Desert Tortoise Project; DTP), was designed to improve terrestrial science and to explore and apply a variety of information science technology, tools, and methods to equip land managers, decision-makers and policy-makers with science-based alternatives for the recovery of the desert tortoise (Gopherus agassizii, federally-listed in 1990 as a threatened species) within the West Mojave Recovery Unit (WMRU) of Southern California, and specifically, within the context of the Ft. Irwin National Training Center (NTC) expansion area.

Three key DTP research objectives were identified:

1. Facilitate better understanding and integration of desert tortoise science and its application to population estimates, habitat evaluation, and threats assessment;

2. Enhance the integration of science with management and policy; and

3. Through the use of information science technologies - including knowledge management, data discovery, modeling and decision support tools - provide an integrated information infrastructure and support for the organization, dissemination, and synthesis of desert tortoise knowledge, information, and data to the scientific, management, and policy community.

During the life of the DTP research program from October 2001 to August 2008, the University completed a diverse range of project-based investigations in the Terrestrial and Geographic Information sciences, developed an extensive collection of spatial data for the Southern California Mojave region, and delivered a significant portfolio of GIS applications and services to the Mojave scientist and land management community on behalf of the Department of Defense.

List of papers submitted or published that acknowledge ARO support during this reporting period. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Heaton, J.S., T.C. Esque, K.E. Nussear, R. Inman, F.M. Davenport, T. E. Leuteritz, P.A. Medica, N.W. Strout, P.A. Burgess, and L. Benvenuti. (2008). Decision Support for Translocation of the Threatened Desert Tortoise. Biodiversity and Conservation, Volume 17, Number 3.

Leuteritz, T.E.J. and H.R. Ekbia. (2006). Not all roads lead to resilience: a comparative study of tortoises in arid ecosystems. Ecology and Society. Volume 13, No. 1.

Number of Papers published in peer-reviewed journals: 2.00

(b) Papers published in non-peer-reviewed journals or in conference proceedings (N/A for none)

Leuteritz, T.E.J. (2006). Tortoises on the march: modeling and GIS relocate a threatened species. GeoWorld 19(5):20-22.

McIntyre, B., T.E.J. Leuteritz, and M.P. Kumler. (2007). A GIS Analysis of the Anthropogenic-Induced Raven Threat to Desert Tortoise. URISA Journal, Volume 19, Number 2.

Number of Papers published in non peer-reviewed journals: 2.00

(c) Presentations

(2003). DTP Decision Support Primer, Appendix I. Desert Tortoise Council Symposium, Las Vegas, NV.

Brenneman, M., Heaton, J. S. and Inman, R. (2003). SPINE. Construction Engineering Research Laboratory, Champaign, IL.

Burgess, P. (2004), US Army Corps of Engineers LA District meeting to provide technology transfer on EMDS for CA Coastal Sediment Master Planning project.

Burgess, P. (2004). Desert Tortoise Management Oversight Group meeting (MOG), Las Vegas, NV.

Burgess, P. (2006). EMDS Workshop, Missoula, MT.

Burgess, P. (2006). U.S. EPA Community Involvement Conference, Milwaukee, WI

Burgess, P., Davenport, F. and Inman, R. (2003). Ecosystem Management and Decision Support (EMDS 3.0). Society for Conservation GIS, Monterey, CA.

Burgess, P., Davenport, F., (2003). Tools for Community Design and Decision Making Conference, San Francisco, CA

Burgess, P., Davenport, Frank, Minor, Andy (2004). Knowledge Modeling and Spatial Analysis of Desert Tortoise Habitat. Desert Surficial Process Workshop, Zzyzx, CA.

Burgess, P., Davenport, Frank, Minor, Andy (2004). Knowledge Modeling and Spatial Analysis of Desert Tortoise Habitat. Mojave Desert Science Symposium 2004, Redlands, CA.

Burgess, P., F. Davenport (2004). Desert Tortoise Habitat Potential Knowledge Base. Whitepaper.

Burgess, P., F. Davenport, R. Inman, S. Hoover (2004). Decision Support Systems. Whitepaper.

Burgess, P., Chris Carter (2005). Results of an Assessment of Land Management Plans. Desert Tortoise Recovery Implementation Work Group, at the CA Department of Fish & Game in Ontario, CA.

Cablk, M., J. Heaton, R. Inman (2004). Efficacy and Reliability of Dogs for Surveying Desert Tortoises: Results from the DT-K9 Trials March 28-April 15, 2004. Desert Research Institute, Reno, NV, Desert Tortoise Conservation Center.

Davenport, F., Burgess, P. (2004). Knowledge Modeling, GIS, and Decision Support for Species Recovery, ESRI International Users Conference, San Diego, CA.

Davenport, F., Strout, Nathan (2005). Spatial Decision Support for Translocating Threatened Species. ESRI International User Conference, San Diego, CA.

Davenport, F., T. Leuteritz, P. Burgess, and N. Strout. (2005). Spatial Decision Support for Translocating Threatened Species. ESRI International Users Conference, San Diego, CA.

Diederich, M. and Davenport, F. (2003). Ecosystem Management and Decision Support (EMDS 3.0). Presented to Construction Engineering Research Laboratory, Champaign, IL.

Diederich, M., Davenport, F., and Inman, R. (2003). Ecosystem Management and Decision Support (EMDS 3.0). ESRI International Users Conference, San Diego, CA.

Ekbia, H. R. (2004). Rethinking DSS: Lessons Learned from Ecosystem Management. Whitepaper.

Ekbia, H. R. (2004). Rethinking DSS. Whitepaper

Ekbia, H. R. (2004). Taking Decisions into the Wild: An AI Perspective in the Design of iDMSS. Whitepaper

Everly, C., and Strout, N. (2007). Deserttortoise.gov: A web portal for Recovery Science and Management. Desert Tortoise Council

Symposium, Las Vegas, NV.

Heaton, J. S. (2002). Desert Tortoise Research at the University of Redlands in the Context of the Fort Irwin Proposed Expansion. Desert Tortoise Council Symposium, Palm Springs, CA.

Heaton, J. S. (2003). Redlands Institute, Desert Tortoise Project. Construction Engineering Research Laboratory, Champaign, IL.

Heaton, J. S. (2003). Revising the Desert Tortoise Recovery Plan In Light of New Science, New Technology, Changing Policies and Changing Times. Joint Meeting of Ichthyologists and Herpetologists, Manaus, Brazil.

Heaton, J. S., (2004). Quantifying the "Search" in Search Dogs for the Desert Tortoise. Poster Presentation. ESRI International Users Conference, San Diego, CA.

Heaton, J. S., Inman, R. (2003). Desert Tortoise Decision Support System. Association of American Geographers, New Orleans, LA.

Heaton, J. S., Inman, R., Burgess, P., Davenport, F. (2004). Desert Tortoise Decision Support: Modeling Knowledge. Desert Tortoise Council Symposium, Las Vegas, NV

Heaton, J. S., Inman, R., Burgess, P., Davenport, F. (2004). Knowledge Modeling and Spatial Analysis of Desert Tortoise Habitat; Poster Presentation. ESRI International Users Conference, San Diego, CA.

Heaton, J. S., Inman, R., Burgess, P., Davenport, F. EMDS Poster Presentation, (2004). Ecological Society of America Conference, Portland, OR

Heaton, J., R. Inman (2004). Line Distance Sampling: Two Years of Support. Whitepaper.

Heaton, J.S. (2004). Desert Tortoise Recovery Plan Assessment Committee (DTRPAC) meeting, Las Vegas, NV

Heaton, J.S., A. Martek, R. Inman, and J. Lesch. (2002) Trends in Desert Tortoise Research: DTC Proceedings 1976-2001. Desert Tortoise Council Symposium. Palm Springs, CA.

Henk, J. (2004). Ecosystem Management and Decision Support in the West Mojave. Construction Engineering Research Laboratory, Champaign, IL

Henk, J. (2004). Emerging Concepts, Methods and Tools for Decision Support: Demonstration of a Knowledge-Based Decision Process for Meeting the Environmental Regulations Related to the Expansion of the Ft. Irwin National Training Center. Marine Corps Base Camp Pendleton Technology Workshop, Camp Pendleton, CA.

Henk, J. (2005). Along the Continuum from Basic to Applied Research. ARO/NGA joint briefing at TEC in Alexandria, VA.

Henk, J. (2005). Spatially-Enabled Decision Support for Ecosystem Management: Integrating Science and Technology to Support Translocation of the Desert Tortoise. ARO briefing at WES in Vicksburg, MS.

Henk, J. (2008) Spatial Decision Support for Adaptive Management of Ecosystems and Species Recovery. 37th Range Commanders Council Environmental Group (REG), U.S. Army Dugway Proving Ground, and at the Army Sustainable Range Workshop in San Antonio, TX.

Hurd, Wendy. (2006). Designing a Geodatabase: Using the Nest Survey Data for the Raven Management Project. Desert Tortoise Council Symposium. Tucson, AZ.

Inman, R., (2004). Search for Missing LDS Focal Animals. Public Lands Class & Field Trip, University of Redlands

Inman, R., Emershy, Chanel, Chesley, Ali (2004). Quantifying the "Search" in Search Dogs for the Desert Tortoise. Mojave Desert Science Symposium Poster Presentation, Redlands, CA.

Inman, R., Heaton, J. S., Brenneman, M. (2003). SPINE. California GIS Conference, Palm Springs, CA.

Inman, R., Heaton, J. S., Burgess, P., Davenport, F. (2004). Desert Tortoise Decision Support: Landscape Analysis. Desert Tortoise Council Symposium, Las Vegas, NV.

Inman. R. (2004). Using K9s to Survey for Desert Tortoise. Society for Conservation Biology presentation, New York, NY.

Johnston, K., Strout, N., and Li, N. (2006) Agent-Based Modeling with Agent Analyst. ESRI International Users Conference, San Diego, CA.

Lesch, J. (2003). CrossMedia Database: Place, Time, and Topic: Integrating GIS and Information Discovery. ESRI International Users Conference, San Diego, CA.

Leuteritz, T. (2005). Biological expert: Population Habitat Viability Assessment (PHVA) Workshop (using PVA Model - IUCN/SSC/CBSG) for two endemic Madagascar tortoises. Republic of Madagascar, Ministry of Environment, Dept. of Water & Forest. Tulear, Madagascar.

Leuteritz, T. (2005). Data Base Management: Use of GRIP for the managing the Ft Irwin Translocation. Conservation Mitigation Working Group, Henderson, NV.

Leuteritz, T. (2005). Research on the Biology of Tent Tortoises (Psammobates tentorius tentorius) at the Tierberg Karoo Research Centre, South Africa. Desert Tortoise Symposium, Tucson, AZ.

Leuteritz, T. (2005). The Use of GIS and Decision Support for the Conservation and Management of an Endangered Species: Translocation of the Desert Tortoise from Military Land. Symposium and Workshop on Threatened, Endangered, and At-Risk Species on DoD and Adjacent Lands, Baltimore, MD.

Leuteritz, T. (2006). Update University of Redlands Desert Tortoise Project 2004-05. Desert Tortoise Council Symposium. Tucson, AZ.

Leuteritz, T. and N. Strout. (2006). Desert Tortoise Awareness. Kimberly Elementary School (Kindergarten & Grade 1), Redlands, CA.

Leuteritz, T., Oftedal, O.T (2006). The Distribution and Abundance of High-PEP Plants in the Mojave and Sonoran Deserts in a Year of High Rainfall. Desert Tortoise Council Symposium. Tucson, AZ.

Leuteritz, T., Paul Burgess, Steve Paplanus, Steve Marsh (2005). Demonstration of Geospatially Referenced Information Portal (GRIP) for Effectiveness Monitoring (based on Dr. Bill Boarman's research data and report). Desert Managers Group meeting, Ventura, CA.

Lewis, L. (2003). Metadata: No Pain, No Gain. Southeast California GIS Council Meeting, San Bernardino, CA.

McIntyre, B. (2003). The Common Raven as a Threat to the Desert Tortoise in the West Mojave, California. Ecological Society of America, Savannah, GA.

McIntyre, B. (2004). The Common Raven as a threat to Desert Tortoise, West Mojave Desert, California. Desert Tortoise Council Symposium, Las Vegas, NV.

McIntyre, B. (2006). Quantifying the Raven Threat in the Translocation Area. Desert Tortoise Council Symposium. Tucson, AZ.

McIntyre, B. a. T. L. (2006). Using GIS to Quantify the Threat and Status of the Common Raven (Corvus corax) at the Ft. Irwin/NTC Translocation Site. ESRI International Users Conference, San Diego, CA.

McIntyre, B., Boarman, William (2005). Spatial Patterns of Raven Nesting and Juvenile Desert Tortoise Predation in the Mojave Desert. Presented at the Ecological Society of America & IX International Congress of Ecology, Montreal, Quebec, Canada.

McIntyre, W. (2004). Spatial Patterns of Raven Nesting and Juvenile Desert Tortoise Predation in the Mojave Desert. Whitepaper.

Murphy, P., Roy Averill-Murray, Catherine Darst, Naicong Li, Serene Ong, Jordan Henk (2008). Collaboration in MCDA/GIS-based Decision Support Systems. U.S. Institute for Environmental Conflict Resolution ECR2008 Program in Tucson, AZ.

Narasimhan, T. (2003). Spatio-temporal Exploration of Grazing Operations in the Mojave Desert. ESRI International Users Conference, San Diego, CA.

Nussear, K., R. Inman (2004). Line Distance Sampling G0: Improving Density Estimates. Whitepaper.

Oftedal, O.T. and T.E. J. Leuteritz. (2006). The Distribution and Abundance of High-PEP Plants in the Mojave and Sonoran Deserts in a Year of High Rainfall. Desert Tortoise Council Symposium. Tucson, AZ.

Ong, S., Horner, L., Desmarais, A. (2008) Desert Tortoise Recovery: Adaptive Management for Changing Landscapes. Poster Presentation. Society for Conservation GIS, Monterey, CA.

Schaffer-Smith, Danica. (2006). Pellet Analysis of Predaceous Birds in the Mojave Desert. Desert Tortoise Council Symposium. Tucson, AZ.

Strout, N. (2004) Land Management Policy Viewer. ESRI International Users Conference, San Diego, CA. Interactive Software Applications Fair.

Strout, N., Ruth Sparks, Linda Massimini (2005). Developing an Application to Manage LRAM Projects at the National Training Center. Annual ITAM Workshop, Indiana Convention Center and RCA Dome; Indianapolis, IN.

Strout, Nathan and Naicong Li. (2006) What is Agent Analyst? ESRI International Users Conference, San Diego, CA.

Tracy, C. R., R. Averill-Murray, W. I. Boarman, D. Delehanty, J. Heaton, E. McCoy, D. Morafka, K. Nussear, B. Hagerty, P. Medica (2004). Desert Tortoise Recovery Plan Assessment. Reno, NV, Biological Resources Research Center (BRRC), University of Nevada. Maps prepared by Lisa Benvenuti.

Number of Presentations: 72.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Leuteritz, T. E. J., R. Ravolanaivo (2005). Reproductive ecology and egg production of the radiated tortoise (Geochelone radiata) in southern Madagascar. Port Elizabeth, South Africa, Zoological Society of Southern Africa. African Zoology.

Leuteritz, T., T. Lamb, J.C. Limberaza (2005). Distribution, status, and conservation of radiated tortoises (Geochelone radiate) in Madagascar, Biological Conservation. 124, Issue 4: 451 - 461.

Li, N. (2007) Smart Knowledge Capture for Developing Adaptive Management Systems. ACM International Symposium on Advances in Geographic Information Systems. Seattle, WA.

Li, N. (2008) Developing a Conceptual Framework for Spatial Decision Support. GIScience Conference. Park City, UT.

Milton, S. J., W. Richard, J. Dean, T. Leuteritz (2005). Opportunistic and Multiple Breeding Attempts in Plants and Vertebrates of Semi-Deserts with Unpredictable Rainfall Events through the Year. Cape Town, South Africa, Transactions of the Royal Society of South Africa. 59 (2): 43 - 53.

Strout, N., Li, N., Agrawal, A. (2007) Integrating ABM and GIS Technologies for Modeling Agent Movement and State Change. American Association of Geographers Annual Meeting, San Francisco, CA.

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):   6

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):   0

(d) Manuscripts

(2008) APPENDIX C, Draft Decision Support System for Desert Tortoise Recovery: A Tool for Evaluating Recovery Action Effectiveness. Draft Revised Recovery Plan for the Mojave Population of the Desert Tortoise (Gopherus agassizii) by Region 8, California and Nevada U.S. Fish and Wildlife Service, Sacramento, California.

Cablk, Mary and Heaton, Jill S. (2005); Efficacy and Reliability of Dogs for Surveying Desert Tortoises: Results from the DT-K9 Trials

McIntyre, B. and T.E.J. Leuteritz. (2006). Quantifying common raven (Corvus corax) threat for desert tortoise (Gopherus agassizii) translocation using GIS. Herpetological Review. Submitted (06/06)

Heaton, J.S., T.C. Esque, K.E. Nussear, R. Inman, F.M. Davenport, T. E. Leuteritz, P.A. Medica, N.W. Strout, P.A. Burgess, and L. Benvenuti. (2006). The use of GIS and decision support for the conservation and management of a threatened species (Gopherus agassizii) being translocated from military land. Conservation Biology. Submitted (08/06).

Number of Manuscripts: 4.00

Number of Inventions:

Graduate Students

NAME	PERCENT_SUPPORTED
Fang Ji (2004)	0.10
Hiroshi Fujiwara (2004)	0.10
Watalu Suzuki (2004)	0.10
Sherry Manning (2006)	0.10
Jennifer Scheineman (2006)	0.10
Anthony Turner (2005-2007)	0.20
FTE Equivalent:	**0.70**
Total Number:	**6**

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
Ken Nussear (2004)	0.25
FTE Equivalent:	**0.25**
Total Number:	**1**

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Blodwyn McIntire	0.12	No
Hamid Ekbia	0.12	No
Jill Heaton	0.12	No
John McIntosh	0.12	No
Lamont Hempel	0.06	No
Thomas Leuteritz	0.06	No
FTE Equivalent:	**0.60**	
Total Number:	**6**	

Names of Under Graduate students supported

NAME	PERCENT SUPPORTED
Alexandra Chesley	0.10
Allison Gravis	0.10
Allison Nymeyer	0.25
Alonna Clark	0.10
Breanna Staggs-Barber	0.33
Chanel Emershy	0.10
Chelsea Smoyer	0.10
Clara Kerley	0.10
Daniel Barber	0.33
Evan Shaw	0.05
Jayaram Reddi	0.10
Jeff Brebner	0.10
Joanna Vance	0.42
Kristen Mobraaten	0.10
Laura Horner	0.10
Lindsey Devlin	0.10
Owen Routt	0.07
Rebecca Ellis-Ferris	0.36
Shellie Churchman	0.10
Stephen Daugherty	0.60
Stephen Marsh	0.10
Thangu Narasimhan	0.10
John Wood	0.10
Alexandra Rackerby	0.10
Amanda Shaffer	0.10
Benton Yetman	0.10
Stephen Francis	0.10
Michael Karg	0.10
Tanya Kohls	0.10
Andrew Miner	0.10
Matthew Ackley	0.10
Celia Chau	0.10
Miles Garber	0.10
Bennit Hughes	0.10
Michael Hunter	0.10
Karel Jedlicka	0.10
Danielle Levine	0.10
Vanessa Prast	0.10
Ja Chun Yoa	0.10
Sean Owins	0.10
Jeff Brogner	0.10
FTE Equivalent:	**5.71**
Total Number:	**41**

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 34.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields: 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields: 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale): 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering: 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: 0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME	PERCENT SUPPORTED	
Bob Baird	0.21	No
Chris Carter	0.75	No
Bob Sporrong	0.47	No
Aditya Agrawal	0.28	No
Dina Guthrie	0.13	No
Frank Davenport	0.75	No
Ian Musto	0.30	No
Jacquie Lesch	0.75	No
Jill Heaton	0.62	No
John Laska	0.37	No
Jordan Henk	0.40	No
Ken Althiser	0.75	No
Kurt Heidelberg	0.63	No
Leticia Franco	0.43	No
Lindsey Devlin	0.23	No
Lisa Benvenuti	0.57	No
Marcus Diederich	0.60	No
Margaret Gooding	0.75	No
Mark Sorensen	0.10	No
Melissa Brenneman	0.75	No
Michael Spencer	0.75	No
Monica Hally	0.44	No
Naicong Li	0.85	No
Nathan Jimerson	0.34	No
Nathan Strout	0.76	No
Paul Burgess	0.52	No
Paula Akompong	0.06	No
Peter Moresi	0.75	No
Petya Maneva	0.67	No
Richard Inman	0.90	No
Rob Lavelle	0.60	No
Ruben Ortiz	0.33	No
Sabine Hoover	0.75	No
Serene Ong	0.75	No
Stephen Daugherty	0.71	No
Steve Hoover	0.75	No
Steve Paplanus	0.76	No
Thomas Leuteritz	0.85	No
FTE Equivalent:	**21.38**	
Total Number:	**38**	

Sub Contractors (DD882)

1 a. University of Nevada - Reno

1 b. Office of Sponsored Projects Administra

2215 Raggio Parkway

Reno   NV   89512

Sub Contractor Numbers (c):

Patent Clause Number (d-1):

Patent Date (d-2):

Work Description (e): Kenneth Nussear,Ph.D. "A model of tortoise activity as a function of the environment with applicati

Sub Contract Award Date (f-1): 3/15/2003 12:00:00AM

Sub Contract Est Completion Date(f-2): 4/30/2004 12:00:00AM

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1 a. University of Nevada - Reno

1 b. Sponsored Projects Administration

M/S 325, 204 Ross Hall

Reno   NV   895570240

Sub Contractor Numbers (c):

Patent Clause Number (d-1):

Patent Date (d-2):

Work Description (e): Kenneth Nussear,Ph.D. "A model of tortoise activity as a function of the environment with applicati

Sub Contract Award Date (f-1): 3/15/2003 12:00:00AM

Sub Contract Est Completion Date(f-2): 4/30/2004 12:00:00AM

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1 a. Desert Research Institute - Reno

1 b. 2215 Raggio Parkway

Reno   NV   89512

Sub Contractor Numbers (c):

Patent Clause Number (d-1):

Patent Date (d-2):

Work Description (e): Mary Cablk, Ph.D.; "Development of non-invasive inventory and monitoring techniques for desert t

Sub Contract Award Date (f-1): 1/1/2003 12:00:00AM

Sub Contract Est Completion Date(f-2): 1/31/2005 12:00:00AM

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1 a. Desert Research Institute - Reno

1 b. 2215 Raggio Parkway

Reno   NV   89512

Sub Contractor Numbers (c):

Patent Clause Number (d-1):

Patent Date (d-2):

Work Description (e): Mary Cablk, Ph.D.; "Development of non-invasive inventory and monitoring techniques for desert t

Sub Contract Award Date (f-1): 1/1/2003 12:00:00AM

Sub Contract Est Completion Date(f-2): 1/31/2005 12:00:00AM

1 a. University of Nevada - Reno

1 b. 755 E. Flamingo Road

Las Vegas   NV   89119

Sub Contractor Numbers (c):

Patent Clause Number (d-1):

Patent Date (d-2):

Work Description (e): Kenneth Nussear,Ph.D. "A model of tortoise activity as a function of the environment with applicati

Sub Contract Award Date (f-1): 3/15/2003 12:00:00AM

Sub Contract Est Completion Date(f-2): 4/30/2004 12:00:00AM

Inventions (DD882)

FINAL REPORT SUPPLEMENT

Application of GIS, Advanced Sensors and Habitat
Modeling in Support of Desert Tortoise Long-term
Sustainability and the Ft. Irwin NTC Expansion
ARO Grant 43074-EV
Agreement: DAAD19-01-1-0793

Contents

Acknowledgements

Abstract

This University of Redlands (University) research program (the Desert Tortoise Project; DTP), was designed to improve terrestrial science and to explore and apply a variety of information science technology, tools, and methods to equip land managers, decision-makers and policy-makers with science-based alternatives for the recovery of the desert tortoise (*Gopherus agassizii*, federally-listed in 1990 as a threatened species) within the West Mojave Recovery Unit (WMRU) of Southern California, and specifically, within the context of the Ft. Irwin National Training Center (NTC) expansion area.

Three key DTP research objectives were identified:

1. Facilitate better understanding and integration of desert tortoise science and its application to population estimates, habitat evaluation, and threats assessment;
2. Enhance the integration of science with management and policy; and
3. Through the use of information science technologies - including knowledge management, data discovery, modeling and decision support tools - provide an integrated information infrastructure and support for the organization, dissemination, and synthesis of desert tortoise knowledge, information, and data to the scientific, management, and policy community.

During the life of the DTP research program from October 2001 to August 2008, the University completed a diverse range of project-based investigations in the Terrestrial and Geographic Information sciences, developed an extensive collection of spatial data for the Southern California Mojave region, and delivered a significant portfolio of GIS applications and services to the Mojave scientist and land management community on behalf of the Department of Defense.

Accomplishments

Accomplishments in Year One (2002):

- **Mapping and Information**. Prepared and delivered nearly 300 '7.5 minute quadrangle maps' (quad) to the US Department of Interior Bureau of Land Management (BLM) in support of their West Mojave Planning Group route designation process. Each quad was processed for quality control by senior GIS staff upon acquisition and prior to delivery to the BLM; 1987-1988 baseline roads were heads-up digitized; data were clipped and edge-matched with adjacent quads. Serviced requests for information (RFIs) by the Desert Tortoise science and management community for maps, documents, and presentations.

- **LDS**. In conjunction with the US Geological Survey (USGS) and Mojave Desert Ecosystem Program (MDEP), developed and delivered a Line Distance Sampling (LDS) electronic data collection system to the US Fish and Wildlife Service (USFWS) in April 2002. Trained field personnel and provided technical assistance for the electronic data collection system throughout the 2002 LDS field season (April-May 2002).

- **Recovery Management**. Prepared and delivered to the Desert Managers Group (DMG) the Summary of Desert Tortoise Recovery Actions report by recovery unit (six units in total) in November 2002. Though an Interagency Agreement, co-hosted (with USGS and the California Department of Fish and Game) the 2002 Desert Tortoise Health and Disease Workshop, in Zyzxx, California.

- **Decision Model**. Successfully completed and released a proof of concept pilot decision support model for Ft. Irwin NTC and its expansion area.

Accomplishments in Year Two (2003):

- **Grazing CD Atlas**. Produced a Grazing Policy CD Atlas, which provides an interactive environment for the spatial and temporal exploration of BLM grazing policies in California's Mojave Desert since the Federal listing of the desert tortoise in 1990.

- **Line Distance Sampling Data Collection Support; Integration and spatial analysis of LDS and Total Corrected Sign (TCS) Tortoise Data; Desert Tortoise Activity Modeling (G_0)**. Provided funding, scientific and technical support to annual population surveys for desert tortoise as conducted by the Desert Tortoise Monitoring and Implementation Committee (USFWS and USGS).

- **Science Support to Recovery Efforts**. Acted as science advisory member to the Desert Tortoise Recovery Plan Assessment Committee, and assisted in preparation of their report.

- **Effectiveness Monitoring**. Worked with USGS and the California DMG on evaluating the effectiveness of actions that have been taken to recover the desert tortoise.

- **Recovery Actions Mapping**. Mapped actions recommended by the desert tortoise recovery plan [Desert Tortoise (Mojave Population) Recovery Plan, USFWS, 1994] per desert wildlife management area (DWMA) and correspondingly indicating the status of agency implementation.

- **Decision Model Development**. Worked with scientists to develop a comprehensive, GIS-based Desert Tortoise Habitat Potential Model that can be used with a Desert Tortoise Habitat Condition Knowledge Base to support decisions regarding tortoise translocation, etc.

- **CrossMedia to SPINE**. Transitioned research from CrossMedia (an internal information technology prototype), creating the architectural design for SPINE (an application which integrates commercial-off-the-shelf tools to provide integrated knowledge management for research groups such as the Ft. Irwin NTC, MDEP, and the DMG).

Accomplishments in Year Three (2004):

- **Population Studies**. Development and implementation of an LDS data management plan based on best practices and methods research. Identification and reporting of spatial errors contained in the 2001-2003 LDS data. Technical support in updating the Personal Digital Assistant (PDA) forms to incorporate changes made in the 2004 LDS field methodology. Supported field trials of exploratory research on the use of dogs trained to detect tortoises.

- **Threat Studies**. Spatial Analysis of Raven Nesting and Juvenile Desert Tortoise Predation. The DTP Science Team (including undergraduate student interns) continued to inventory raptor (primarily raven, *Corvus corax*) nests in the Mojave Desert.

- **Grazing Policy Viewer**. The Grazing Policy Viewer was created to aid understanding of the current and historic state of grazing and ranching policy in the Mojave Desert. It synthesizes key content from policies issued on sheep and cattle ranching since 1990 and associates them with their spatial footprint (the geographic area to which they apply). Using a mapping interface and a navigation tree, the user can visualize the extent of ranching policies, understand how those policies and their geographic limits have changed over time, and formulate basic queries

that summarize the state of grazing restrictions for a given year (or years). The Grazing Policy Viewer promotes improved understanding of land management policy using geography as its principle point of reference.

- **Integration of Ecosystem Management Decision Support (EMDS) into ArcGIS Geoprocessing/ModelBuilder**. The Decision-Support System (DSS) team initiated a collaborative, coordinated effort to extend the current EMDS software concept and integrate its components within the ESRI ArcGIS Geoprocessing/ModelBuilder environment. The DSS team hosted a workshop with the EMDS developers in late September to assess functional requirements for implementing this transition.

- **SPINE**. In 2004, research and development of SPINE continued with evaluation of two development platforms from ESRI including the ArcReader Control and ArcServer. The ArcReader Control was used to develop the Grazing Policy Viewer as a prototype for SPINE, and was determined to be limited (in customizability) for the SPINE application. ArcServer has since been evaluated and determined to be a more viable development platform allowing for a full web deployment with a variety of customizable functionality. A prototype was developed using grazing data consisting of 21 spatial features and 21 documents to display functionality. The full implementation will consist of approximately 2,000 documents and 200,000 spatial features.

Accomplishments in Year Four (2005):

- **Threat Studies – Raven Predation**. Dr. Blodwyn (Wendy) McIntyre continued her research on ravens as a threat to the desert tortoise. During the month of June 2005, approximately 70% of known predaceous bird nests in the Mojave Desert were located, spatially referenced, and reviewed to (1) identify species of bird occupying the nest, and (2) to determine which nests have "evidence" of predation on juvenile desert tortoises. Pellets were also collected at each nest to further the work of a University of Redlands senior capstone project - 'Conducting a Dietary Analysis of Predaceous Birds across the Desert'. The significance of this work is that "known offenders", or ravens that appear to be preying on juvenile desert tortoise are identified and mapped spatially. This information was provided to the DMG's Raven Management Team for an Environmental Assessment for proposed management actions to control raven predation on desert tortoise in the Mojave. Dr. McIntyre worked with the tortoise translocation science team to apply the methods pioneered in her field research to completing a baseline raven survey in the designated receiving areas for the upcoming tortoise translocation effort.

- **Range-wide Survey of Tortoise Food Plants**. Conducted a systematic survey of high-PEP (Potassium Excretion Potential) plants across the range of tortoises (from the West Mojave and Colorado deserts through southern, central and northern Arizona to southern Nevada and

southwestern Utah) at 30 sites in four states (CA, AZ, NV, UT) over the period of 6 April 2005 - 7 May 2005. Emphasis was given to habitats where long-term tortoise population trends have been and will continue to be monitored. A systematic study of the abundance of high-PEP plants across tortoise habitats has never been done. If high-PEP plants are generally scarce, this may be a consequence of 150 years of livestock grazing and invasion by competing exotic annuals, both of which could have reduced seed production (and thus the long-term seed bank) of these species. If so, enhancing seed banks of high-PEP plants may be a viable target for desert restoration work.

- **Land Management Plan Review**. Delivered a database that synthesizes planned and ongoing activities as well as policies towards desert tortoise recovery. Developed a dataset that can be used in a GIS-based application (ArcGIS Server) to deliver information about the status of the recovery effort to a distributed audience over the Internet. Provided critical information for ongoing initiatives to improve coordination and management of desert tortoise recovery. The product of the management plan review is being used by a consortium of desert tortoise scientists and managers to inventory the planned and ongoing activities to recover desert tortoise throughout its range. The inventory is being used to seed an initiative to better coordinate recovery activities and to inform the revision of the Desert Tortoise Recovery Plan originally published in 1994.

- **Effectiveness Monitoring for the Desert Tortoise Recovery Program**. Developed a database for capturing and synthesizing highly distributed information related to desert tortoise management. Developed maps that accompany a peer-review publication quality report on the effectiveness of recovery actions. Developed a prototype system for tracking and analyzing recovery activities by a distributed network of resource managers. Completed visualization tools including interactive charts and maps to display the evaluation results on the effectiveness of actions taken to recover the desert tortoise as documented in scientific, peer-reviewed literature and land management documents. Visualization tools were presented in May 2005 at BLM/USFWS office and the aforementioned July 2005 DMG meeting. The study was the first effort to take stock of the effectiveness of recovery actions taken to date. It was also the first effort to assess the state of knowledge about historic actions and their usefulness in tortoise recovery. The prototype web-based viewer could be further developed and eventually deployed as an online system for tracking and analyzing what actions are being taken where and their effectiveness at recovering desert tortoise populations and/or habitat.

- **GIS-Based Decision Support for the Translocation of Desert Tortoises (Gopherus agassizii) from Ft Irwin, National Training Center, CA**. The DTP team collaborated with key Army, US Fish and Wildlife Service (USFWS) and US Geological Survey (USGS) scientists to develop a knowledge base

(an ecosystem/landscape assessment model) that combined data on attributes about tortoise habitat, threats to tortoises, recent tortoise population surveys and important anthropogenic factors (e.g., land ownership, road status, projected urban growth). This knowledge-base model was used to drive an inference engine that provided a geospatial assessment of translocation alternatives (both locational and management alternatives) as the basis for developing a decision model. The decision model included several scenarios of the suitability of lands in the west Mojave Desert for translocation of tortoises based on multiple criteria, such as conservation history, land ownership attributes, habitat suitability, level of habitat disturbance, accessibility by the public, and the presence of major roads (with fenced and unfenced scenarios). These scenarios were presented to the Translocation Implementation Committee to aid in a final consensus on the most suitable sites for translocation. After three months of developing the model, the results were presented to the land managers at the Translocation Implementation Committee (composed of members from the BLM, USFWS, California Department of Fish and Game, DOD, and the Department of the Interior). After multiple internal reviews of the scenarios, the committee picked two translocation sites that were then 'ground-truthed' by several of the committee members using a DOD helicopter. In addition to decision support via modeling the value of potential translocation sites for the tortoises, the project's technology and methodology was disseminated through a presentation at the Technical Symposium and Workshop: *Threatened Endangered, and At-Risk Species on DOD and Adjacent Lands.* Baltimore, MD. June 7-9, 2005 (http://www.serdp.org/tesworkshop/), as '*The Use of GIS and Decision Support for the Conservation and Management of an Endangered Species: Translocation of the Desert Tortoise (Gopherus Agassizii) from Military Land*'.

- **Interactive Geo Referenced Information Portal (GRIP)**. Completed system design and prototyped a geospatial web portal/knowledge management infrastructure utilizing Microsoft's ASP.NET, Environmental Systems Research Institute's (ESRI) ArcSDE and ArcGIS (the GIS components), and Clusterizer from CyberTavern (to handle dynamic clustering of search results). The initial portal was presented at the July 2005 Desert Managers Group meeting in Ventura, CA.

- **Land Rehabilitation and Maintenance (LRAM)** Tools for the Integrated Training Area Management Program (ITAM). The DTP technology team developed a set of tools with ESRI's ArcGIS (office compilation and analysis) and ArcPad (field data collection). The LRAM application was intended as a tool to improve management of project sites throughout their life cycle, allowing the user to query and modify attributes of the project, link digital photos and documents to the project, and create reports. This technology was demonstrated at the 2005 ITAM conference in Indianapolis, ("Developing and Application to Manage LRAM Projects

at Ft. Irwin") which generated numerous requests by other installation ITAM managers for the application.

- **Collaboration to Enhance Emerging GIS Technologies: Agent Modeling and Simulation**. The DTP team worked with Dr. Kevin Johnston at ESRI to support a team of simulation modelers from the Argonne National Laboratories, University of Chicago, University of Michigan, Hunter College, and others to integrate the RePast simulation tool as an Agent Analyst extension for ArcGIS. This emerging technology should have significant utility for modeling and visualizing alternatives within a decision support/problem-solving context; agent modeling has a strong potential application for DOD operations. DTP staff attended the beta training session for Agent Analyst, and agreed to serve as the steward for user support, and to coordinate product training and outreach. Website: http://www.spatial.redlands.edu/agentanalyst/ .

- **Collaboration to Enhance Emerging GIS Technologies: Ecosystem Management Decision Support (EMDS)**. The DTP team continued its role in stewarding a collaborative, coordinated effort to extend the Ecosystem Management Decision Support (EMDS) software concept and integrate its components within the ESRI ArcGIS Geoprocessing/ModelBuilder environment. In late September of 2004, the DSS team organized a workshop with the EMDS developers to assess functional requirements for implementing this transition. The team (RI, ESRI, USGS, InfoHarvest and Rules of Thumb) agreed to a re-engineering design and planned for implementation of their respective software enhancements. EMDS tools were used to perform the translocation analysis and to support the Lower Mississippi River Conservation Committee (LMRCC) restoration decision model. The US Forest Service approved a Memorandum of Understanding (MOU) that recognized the University of Redlands as the EMDS steward responsible for user support and product enhancement coordination.

- **Case Study: Decision Model for Lower Mississippi River Restoration**. DTP staff worked with ERDC staff at the Waterways Experiment Station (WES's Andrew Miller, PhD.; Research Limnologist; Chief, Aquatic Ecology & Invasive Species Branch), Philip Murphy, Ph.D.; CEO of InfoHarvest (developer of Criterium Decision Plus), and state and federal representatives from the LMRCC to develop a decision model for prioritizing among more than 230 agency-identified restoration alternatives. This model was prepared with a small workshop 26 April 2005 at WES, and presented for the LMRCC group during the 2005 conference in Tunica, MS. This project was intended to demonstrate how spatial decision support tools could be applied to model ecological restoration alternatives, and to eventually improve the US Army's Corps of Engineers' civilian operations in restoring and maintaining the lower Mississippi River.

Accomplishments in Year Five (2006):

- **Raven Threat Baseline Study**. Dr. Blodwyn (Wendy) McIntyre and two former University of Redlands students (Jennifer Scheineman & Sherry Manning) conducted a three month pilot study on the baseline status of ravens (Corvus corax) at the tortoise translocation site. The objective of the study was to quantify the threats ravens pose to 'translocated' desert tortoises in the translocation area designated by the Conservation Mitigation Working Group (CMWG). This pilot study outlined methodologies to quantify the predation threat posed by what may be considered the most important predator of desert tortoise, the common raven.

- **GRIP**. Continued development of the Geo Reference Information Portal. The prototype was extended as the basis for subsequent application for the USFWS, the NTC, and Yuma Proving Ground (in collaboration with ERDC Construction Engineering Research Laboratory; CERL). The objective of this project is to develop a system framework to support spatially-enabled knowledge management applications. The first phase of this framework development focused on data discovery, retrieval, and visualization of desert tortoise scientific information. The phase completed in July of 2006 provided an adaptable user interface (web and/or desktop), and supports the integration of searches and databases from multiple sources (local files systems, network databases, search engines, etc.)

- **EMDS**. Continued our research and development as the official steward (under MOU with the US Forest Service [USFS]) for Ecosystem Management Decision Support (EMDS), a GIS-enabled decision support toolset developed by the USFS. We maintained the public access website (see http://www.spatial.redlands.edu/emds/) and held a developer workshop with our collaborative team of partners (Dr. Keith Reynolds, US Forest Service Pacific Northwest Research Station; Dr. Philip Murphy, CIO of InfoHarvest, Inc.; Dr. Michael Saunders, Professor at the Pennsylvania State University; Mr. Bruce Miller, President of Rules of Thumb, Inc.; and software developers from the Environmental Systems Research Institute).

- **Agent Analyst**. University researchers attended the Repast modeling conference in late Fall, 2005. Built and deployed a new web portal for dissemination of information and technical support. See: http://www.spatial.redlands.edu/agentanalyst . Built two new GIS-centric models and a training tutorial that were presented in August 2006 at the ESRI International User Conference.

- **Case Study: Analysis of Riparian Biological Opinion Management at Camp Pendleton**. This technology-transfer case study involved the use of GIS technology developed for the DTP to assist Camp Pendleton's Assistant Chief of Staff, Environmental Security (AC/S ES), Natural Resources

Department (Natural Resources) in assessing their implementation of the management actions required by the Riparian Biological Opinion (BO) approved by the US Fish and Wildlife Service (USFWS). The objectives of the project were (1) to assess the status of Natural Resources' riparian area management actions to ensure that the requirements of the Riparian BO are being met, (2) to assess the effectiveness of the Riparian BO and Natural Resources implementation relative to improved habitat quality and species distribution, and (3) to analyze the relationship of Natural Resources' management actions to constraints in operational mission as the basis for identifying potential areas where adjustments might reduce natural resource management constraints. Conducted assessment of approximately 300 species- and habitat-based management actions relative to the requirements of the Riparian Area Biological Opinion. Linked the assessment data to Camp Pendleton's GIS database. Built a set of landscape assessment and decision models to illustrate how 'optimal management' could be planned, monitored and refined in an adaptive management approach. Built a custom GIS-based data viewer/reporter given very strict constraints for Camp Pendleton's information technology (IT) platform.

- **Outreach**. The Desert Tortoise Project continued its outreach in 2005-2006 by attending Desert Mangers' Group (DMG) meetings in Primm NV (Oct 05), Palm Springs CA (Jan 06), Barstow CA (Apr 06), and Big Bear CA (Jul 06). We continued our collaboration with USGS through field work done by Dr McIntyre on ravens in the translocation area and the preparation of our publication, *On the Use of GIS and Decision Support for the Conservation and Management of a Threatened Species (Gopherus Agassizii) Being Translocated from Military Land*, to be submitted to *Conservation Biology*. Worked with the US Fish and Wildlife Service (USFWS) on Desert Tortoise recovery conflict resolution undertaken by the US Institute for Environmental Conflict Resolution (USIECR). In April, hosted a stakeholder meeting conducted by the Mojave Desert Ecosystem Program (MDEP) and USIECR to select a conflict resolution specialist that would handle the California component of the conflict resolution process. The stakeholders choose a team from the California State University Sacramento's Center for Collaborative Policy to represent California.

Accomplishments in Year Six (2007):

- **Agent Analyst/Dynamic Modeling**. The University continued to maintain the open research community website for Agent Analyst. We completed several demonstration models and presented them at several technology transfer venues. Of note was our participation with research staff from ESRI at the UCSB Specialist Workshop "Workshop on Agent-Based Modeling of Complex Spatial Systems" held in Santa Barbara on April 14-16, 2007. Our research collaborative gained approval from ESRI Press to author a reference book on Agent Based Modeling (in progress as of August 2008).

We also presented work in agent movement and state change (through urban growth model, bird migration model, etc.) at the workshop and at Association of American Geographers annual conference (AAG 2007).

- **Desert Tortoise Recovery**. In January of 2007 we began a high-priority support project for the US Fish and Wildlife Service (USFWS) Desert Tortoise Recovery Office (DTRO) to apply our geographic information science (GIS) research in spatial decision support toward the update of the Desert Tortoise Recovery Plan. The original desert tortoise recovery team recognized the importance of including new data and analyses related to tortoise recovery efforts as they become available, as part of an adaptive management approach. The University assisted the USFWS DTRO to develop a revised Recovery Plan for the Desert Tortoise. We completed an inventory and assessment of 250+ GIS data sets, identified 12 data gaps, and compiled data updates for Clark County, NV; Nevada Dept. Of Wildlife (NDOW; the Arizona Strip; and the Mojave National Preserve. As a part of this process, land management agencies across the Mojave were consulted in a series of workshops aimed at identifying practical, scientifically justified management actions that will lead to the recovery of the species. During these workshops, we mapped 217 additional threats and 131 recovery actions. In partnership with the DTRO and a consortium of private, non-profit and public entities, the University began development a decision support system that will allow managers to prioritize their recovery actions, evaluate their costs and benefits and visualize potential outcomes of alternative management scenarios in a GIS. This system will ultimately be used to monitor species recovery using an adaptive management approach.

- **Desert Tortoise Information Portal**. In 2007 the University continued collaboration with the Mojave Desert Ecosystem Program (MDEP) to develop a one-stop information portal. Our team contributed to the architecture, user interface design and service components. We applied our research in spatially-enabled knowledge management to develop a server-based GIS function for the portal. The University's entire digital desert tortoise science spatial data collection was transferred to MDEP for publication. This portal is online at http://www.deserttortoise.gov/.

- **Spatial Decision Support Systems**. Continued our investigation into spatially enabled decision support systems (SDSS). We developed an SDSS SharePoint site for organizing project materials as well as to facilitate collaboration with our research partners. We initiated a focused literature review process on SDSS methodologies and tools, which produced an internal knowledge repository of over a hundred published books, papers, online documents, relevant research and tools sites, etc. We began the process of reviewing and synthesizing these resources. The literature review and synthesis will drive the development of a set of controlled vocabulary terms for the field of SDSS, and our initial version of this has been stored on the SDSS SharePoint site. The vocabulary is the basis for

developing an ontology for SDSS in OWL. We created an initial HTML browsing version of this ontology stored on the SDSS SharePoint site.

- **EMDS**. Continued research and development as the official steward for Ecosystem Management Decision Support (EMDS). We held our second developer workshop and completed an engineering specification for development of a new version of EMDS that streamlines the application for ease of use by DOD installation researchers and land managers.

- **GRIP/Knowledge Management**. We continued to refine and apply our work in knowledge management. We completed an investigation of open source and commercial packages for implementing the ontology-driven information organization and retrieval component. We continued progress with the development of a prototype ontology for desert tortoise science that we hope will improve research for the tortoise science and management community. Our design applies an ontology-driven information organization and retrieval component for accessing DTP information repository using the prototype DTP ontology. This work was presented at AAG 2007.

Accomplishments in Year Seven (2008):

- **Updated LRAM Tool**. Under ARO grant research, The University of Redlands developed and deployed a new version of its Land Rehabilitation and Maintenance (LRAM) Project Tracker tool for use by the LRAM team the US Army National Training Center (NTC Ft. Irwin). The LRAM Project Tracker provides GIS-based tools to standardize both in-field and in-office work processes for better management of LRAM project site data.

- **Release 4.0 of the Ecosystem Management Decision Support (EMDS) System**. In 2007, at the request of the Forest Service, the University engineered an emergency version of EMDS 3 (v 3.2) to support national level resource planning by forest for the 2007-2008 forest fire season. In 2008 and under partial Forest Service funding, the University completed a comprehensive redesign of the EMDS architecture to better leverage newer technologies, such as Microsoft's .NET framework, ESRI's Geoprocessing framework, and the de-facto industry web standards for a Service Oriented Architecture (SOA). The new architecture was designed using SOA techniques based on a modified iDesign's Architecture Development Method to ensure that it would be flexible and robust, easily extensible, and compliant with Windows Communication Foundation (WCF). EMDS functional subsystems were re-engineered into a series of WCF services that formed the basis of the entire system, enabling a coding structure that abstracted the underlying service engines and the application logic and processing tiers of the system, and which enabled us to support multiple different front-end clients, including an ArcMap extension and a standalone ArcEngine application. A completely engineered, new version of EMDS (v 4.0) was presented to the user

community at the ESRI International User Conference in August 2008. This public-domain application suite has extensive potential for use by federal land managers and decision makers. EMDS Website: http://www.institute.redlands.edu/emds/

- **Case Study: Knowledge Management for Natural Environments Test Office (NETO) at Yuma Proving Grounds (YPG)**. Under ARO grant research, the University of Redlands has been working with the Natural Environments Test Office (NETO) / the Sustainable Range Program (SRP) / Yuma Proving Ground (YPG) / ERDC Construction Engineering Research Laboratory (CERL) to develop a limited, web-GIS based prototype that unifies topical and spatial information retrieval and synthesis across disparate data sources. This technology-transfer case study involved the use of GIS technology developed for the DTP to assist Yuma Proving Grounds with knowledge management. YPG's offices of Environmental Sciences and Natural Environments Testing each have responsibilities related to understanding and managing at the Army's impact on the natural environment; and the environment's impact on the Army. Both offices generate and utilize disparate sets of data and information to support their missions: data associated with a wide range of processes, protocols, systems, and databases. The focus of this project was to explore how the information collected and used by the two offices can be effectively combined and accessed to enhance the value and utility of this knowledge for each office's respective mission. On 13 AUGUST the Redlands / NETO / SRP / YPG / CERL team briefed representative of YPG staff, including YPG Technical Director, NETO and SRP personnel, and representatives of Yuma Test Center, Plans and Operations, Advanced Technology, and Public Works Directorates. The prototype demonstrated ability to use GIS searching to produce prioritized data from a variety of media and formats originating from many disparate sources – public, legacy – at multiple scales. Prototype features included:

  - Web-based application (decision made in order to provide YPG user access, given IT security constraints within DoD precluding introduction of new software)
  - Full-featured web mapping application
  - Explorer tools (simplified access to routine quick information) for navigating global deserts, TIR, HIVE and LCTA.
  - Search tool (advanced searching and filtering capabilities)
  - Framework to support hierarchical map navigation
  - Gazetteer: compiled publically available and YPG placenames (for Mobility Courses), aliases, geometry, and typing scheme
  - Enhanced query tool for public data sources such as Defense Technical Information Center (DTIC)
  - Framework for querying standard mapping and metadata services
  - Parsing Test Incident Report (TIR) databases (Palletized Loading System) to support report generation and basic queries

- Integrated NOAA's National Digital Forecast Database (NDFD) web service
- Compiling multiple sources and types of data for building the YPG prototype knowledge base
- Implementation of TIR, DTIC, Geography Network, & STINET as GRIP datasources

- **Desert Tortoise Recovery**. Under ARO grant research, and as initiated by recommendation of the California Desert Manager's Group (DMG), the University of Redlands continues to work in collaboration with the US Fish and Wildlife Service (USFWS) Desert Tortoise Recovery Office (DTRO) to develop the spatial data infrastructure and decision support framework envisioned by USFWS-DTRO as the basis for an adaptive management and monitoring program that will aid collaborative management efforts among federal, state and local agencies working for the recovery of the desert tortoise. The DMG and DOD installations in the California-Nevada-Arizona Mojave Desert are key agencies in the Desert Tortoise Recovery process. Using spatial decision support technologies and an adaptive management approach in DTRO's recovery planning process produced a number of benefits. It enhanced the utility of existing geospatial data on tortoise threats and recovery actions, and ensured the efficient use of these data in prioritizing actions. More importantly, it improved the planning process by (1) enabling managers to visualize and analyze spatial relationships between threats, recovery actions, and agency jurisdictions; (2) facilitating open dialogue about agency priorities for recovery action;(3) making transparent the relative contribution of decision criteria to recovery actions; and (4) fostering consensus on appropriate combinations of actions for the Recovery Plan. The prototype DTRO SDSS developed by the Redlands Institute and InfoHarvest, Inc., was used to identify recommended actions for inclusion in the revised Recovery Plan. This draft Plan currently is undergoing an internal and public review prior to implementation. The ultimate vision for the DTRO SDSS is a set of web-based data visualization, assessment and reporting tools that provide user-friendly access to relevant spatial and non-spatial databases through the Desert Tortoise Web Portal (http://www.deserttortoise.gov). The DTRO SDSS will also support monitoring and evaluation of progress and effectiveness of recovery actions, a key but often overlooked step in the adaptive management cycle. Creating a system of adaptive management fosters a process of constant evaluation and redesign, which enables better implementation of recovery planning, and better recovery of the endangered desert tortoise. The University presented 'Spatial Decision Support for Adaptive Management of Ecosystems and Species Recovery' on 18 March at the 37th Range Commanders Council Environmental Group (REG) held at the U.S. Army Dugway Proving Ground, and on 9 JULY at the Army Sustainable Range Workshop in San Antonio, TX. Presented 'Collaboration in MCDA/GIS-based Decision Support Systems' on 22 MAY at the U.S.

Institute for Environmental Conflict Resolution ECR2008 Program in Tucson, AZ. The summary of this work was published as APPENDIX C, DRAFT DECISION SUPPORT SYSTEM FOR DESERT TORTOISE RECOVERY: A TOOL FOR EVALUATING RECOVERY ACTION EFFECTIVENESS, August 29, 2007 in the Draft Revised Recovery Plan for the Mojave Population of the Desert Tortoise (Gopherus agassizii) by Region 8, California and Nevada U.S. Fish and Wildlife Service, Sacramento, California.

- **Spatial Decision Support (SDS)**. "Spatial decision support is the computational or informational assistance for making better informed decisions about problems with a geographic or spatial component. This support assists with the development, evaluation and selection of proper policies, plans, scenarios, projects, interventions, or solution strategies" (The SDS Consortium). In this project, we have developed a set of ontologies to represent the body of knowledge on spatial decision support (SDS). This set of ontologies is an initial attempt at capturing the essential concepts in the SDS field of study, their properties and relations among them, as well as information about the SDS resources. We have also developed a web-enabled SDS Knowledge Portal (http://www.institute.redlands.edu/sds/) to present SDS related knowledge and information. The SDS ontologies provide a conceptual framework for organizing the content on the Portal, as well as guiding the content browsing and search on the Portal. In 2008, the University chartered a Spatial Decision Support Consortium and held two expert workshops to design and develop a secure knowledge portal for Spatial Decision Support (SDS). At the invitation of the University of Redlands, a number of researchers, experts and practitioners joined this research effort early 2008, participating in two collaborative workshops and providing individual contributions. An informal SDS Consortium was formed in May 2008. The current content of the Knowledge Portal reflects the collective effort of the SDS Consortium members. The Spatial Decision Support (SDS) Knowledge Portal project objectives include (1) developing a systematic representation of the existing body of knowledge in the field of SDS; (2) promoting semantic clarity of commonly used terms within a user community, in the areas including decision process, methods and techniques, functionalities of Spatial Decision Support Systems (SDSS); and (3) organizing a representative set of existing SDS reference resources including literature, tools, and case studies. Although this work is far from complete, we hope our work provides a good theoretical and methodological foundation for the future growth of the SDS Knowledge Portal, in which we plan to develop a library of modular, reusable SDSS components. A large number of open-source and commercial SDSS related software, algorithms, and tools have been developed to date. With few exceptions, these components have been built independently from scratch for each application, are not easily reusable, and their performance is not independently verifiable. The lack of component modularity contributes to the lack of reusability in these tools. Developing

reusable SDSS components depends on a high level of understanding of the SDS including the identification of the fundamental granules of the SDS process. Such an understanding is difficult to achieve, given the lack of systematic integration and presentation of knowledge in SDS. The SDS Knowledge Portal project was designed serve as a learning platform to better understand the decision process, to explore the available resources, and to serve federal land managers and decision makers.